

## TELESCOPING CAMERA CRANE

### BACKGROUND OF INVENTION

**[0001]** The field of the invention is camera cranes.

5 **[0002]** Camera cranes are often used in motion picture and television production. The motion picture or television camera is typically mounted on a crane arm supported on a mobile base, dolly, or truck. The mobile base may be pushed and steered by hand. Larger units, which have more weight carrying capacity, and longer reaches, typically have electric driving motors powered by onboard batteries.

10 Some mobile bases also including conventional gasoline or diesel engines, may also serve as over the road vehicles.

**[0003]** Camera cranes generally have a crane arm supported on a base, with a camera platform at one end of the arm, and a counter weight at the other end. The crane arm can be pivoted by hand to raise and lower the camera, and also to

15 pan to the left or right side. A leveling system is often included to maintain the camera platform in a level orientation, as the elevation angle of the arm changes. Some mobile bases may include a self leveling or an extendible center post or column, which the crane arm can be mounted on.

**[0004]** With the development of high definition digital television cameras, and

20 remote controlled motion picture cameras, filming can be achieved without a camera

operator behind the camera. Rather, the remotely-controlled camera may be suspended on a crane arm, with the camera operator monitoring the image captured by the camera via a remote monitor.

**[0005]** Due to the variety of filming or video locations, the camera crane arm

5 should advantageously be portable and lightweight. On the other hand, the arm must be rigid enough, when assembled, to resist bending and sagging, and to avoid excessive whipping motion of the camera during crane arm movement. Most camera cranes are made up from modular segments or sections, and have a fixed length. The segments are joined together until an arm of desired length is formed.

10 With these types of arms, the length can be changed only by adding or removing segments. This is a time consuming process, as segments and leveling arms are bolted into place or removed. In addition, each time the length of the arm is changed, the arm must be rebalanced, by adding or removing counter weights. More importantly, crane arms having a fixed length cannot achieve various camera

15 movements.

**[0006]** As a result, telescoping camera cranes have been developed. These types of cranes have a telescoping arm that can extend and retract. This allows for a much broader range of camera movement. While existing telescoping camera cranes have had varying degrees of success, existing designs have several

20 disadvantages. Generally, the telescoping camera cranes available now use

various electrical systems. Consequently, these cranes tend to have performance problems if used in rain or wet conditions. Attempts to avoid or reduce these problems by wrapping or tenting the electrical components provide mixed results.

Of course, these types of cranes also cannot be used underwater. In addition,

5 these types of cranes tend to be very large, heavy, and bulky. This makes transportation and set up time consuming and difficult. As production time is usually extremely expensive, time saving features are highly significant.

[0007] Moreover, under certain conditions, these types of telescoping cranes can cause unintended or undesirable camera movements, due to bending, flexing,  
10 twisting, or vibration of the crane arm. Noise generated from moving parts in these types of cranes, when the arm is extended or retracted, can also disrupt filming or recording.

[0008] Accordingly, various engineering challenges remain in designing an improved camera crane.

## 15 SUMMARY OF THE INVENTION

[0009] After extensive research and development by the inventor, a novel telescoping camera crane is provided with various new features and advantages. In a first aspect, the camera crane has mechanical drive and camera platform leveling systems. Consequently, the camera crane is essentially waterproof. While  
20 waterproof or water resistant enclosures have been made for cameras, until now,

little or no such parallel developments have been made for camera cranes. Now, however, with the inventor's new crane, previously unknown and dramatic camera movements and angles can be achieved. For example, using the present crane, the camera can move down toward a water surface, and then pass through the water surface into a submerged position, in a single continuous movement, and without  
5 moving the mobile base, vehicle or dolly supporting the crane. In another example, the camera can approach, and move directly through a waterfall, in a continuous movement, with no movement of the mobile base required.

**[0010]** In a second and separate or independent aspect, the telescoping

10 sections of the present crane are driven by a novel hydraulic system. This provides exceptionally smooth and near silent extension and retraction movement. This movement can also be precisely controlled. The hydraulic system includes a novel hydraulic cylinder having piston attached around a cable extending through the cylinder. This design provides a very long piston travel length for moving the  
15 telescoping sections. However, it is highly compact and efficient.

**[0011]** In a third aspect, the telescoping sections are hollow rectangular or square tubes. Multiple rollers support the tubes within each other. Due to the high strength of the sections, the roller spread or area is reduced, providing for a longer extended length of the crane arm. Consequently, the crane arm is relatively

20 compact, and lightweight, yet provides a surprisingly long extended reach. The

rollers are preferably a relatively softer material. This allows the rollers to absorb vibration and provide quiet operation.

**[0012]** In a fourth aspect, the center post supporting the crane arm is inclined rearwardly. This helps to reduce shifting of weight on the pan axis bearing during panning movements of the crane arm. Inadvertent movement of the camera caused by deflection of the mobile base during panning movements, is reduced.

**[0013]** In a fifth aspect, the moving sections of the arm have a slight upward curvature or radius. This subtle change in the shape of the arm sections improves performance. The curvature is selected to compensate for deflection or sagging of the arm when loaded. Consequently, in normal use, the arm remains nearly perfectly straight. Lateral whipping movements, resonance, torquing, or other undesirably affects, are reduced or eliminated, because the center of gravity of the load on the arm remains centered on the axis of the arm.

**[0014]** In a another aspect, a riser or extender section on the arm increases the effective length or reach of the arm. The extender section may also be pivotably mounted on the arm, so that it can quickly be moved into overslung, underslung and 90 degree or side positions. This feature extends the vertical up or down reach of the crane and also allows for quick balancing of a remote camera head attached to the arm.

**[0015]** In another aspect, a novel hydraulic valve provides precise control of the hydraulic actuator, and hence precise control of the arm movement and position.

**[0016]** Other aspects and advantages will be apparent from the following detailed description and drawings. The invention relies as well in subcombinations and subsystems of the elements described. For example, each of the features listed above can be used as an improvement in a conventional crane design. Alternatively, they may be used in various combinations with each other.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

**[0017]** In the drawings, wherein the same reference number indicates the same element in each of the views:

**[0018]** Fig. 1 is a side view of a novel telescoping crane, mounted on a mobile base or vehicle, with the crane in the retracted position.

**[0019]** Fig. 2 is a side view of the crane shown in Fig. 1, with the arm now fully extended.

**[0020]** Fig. 3 is a partial perspective view showing various components of the crane arm shown in Figs. 1 and 2.

**[0021]** Fig. 4 is a plan view of the crane arm shown in Fig. 1.

**[0022]** Fig. 5 is an enlarged side view of the crane arm shown in Fig. 1.

**[0023]** Fig. 6 is a plan view of the present crane arm in the fully extended position.

**[0024]** Fig. 7 is a side view thereof.

**[0025]** Fig. 8 is a partial section view taken along line 8-8 of Fig. 5.

5 **[0026]** Fig. 9 is a section view taken along line 9-9 of Fig. 6.

**[0027]** Fig. 10 is a partial plan view of the back end of the crane arm shown in Figs. 3-7.

**[0028]** Fig. 11 is a side view thereof.

**[0029]** Fig. 12 is an enlarged plan view of the front end of the second arm  
10 section shown in Fig. 6.

**[0030]** Fig. 13 is a side view thereof.

**[0031]** Fig. 14 is an enlarged plan view of features shown in Fig. 4.

**[0032]** Fig. 15 is a side view thereof.

**[0033]** Fig. 16 is an enlarged side view of the front end of the crane arm  
15 shown in Figs. 2 and 7.

**[0034]** Fig. 17 is a plan view thereof.

**[0035]** Fig. 18 is an enlarged plan view, in part section, of the crane arm in the retracted position, as shown in Figs. 4 and 5.

**[0036]** Fig. 19 is an enlarged side view, in part section, of the nose plate of the present crane arm.

5 **[0037]** Fig. 20 is a plan view thereof.

**[0038]** Fig. 21 is a top view of a roller bracket assembly for installation in the front end of the second section, as shown in Figs. 12 and 13.

**[0039]** Fig. 22 is a side view of the roller bracket shown in Fig. 21.

**[0040]** Fig. 23 is a perspective view diagram showing the second or a center  
10 section drive cable connecting the counter weight carrier and the center tube.

**[0041]** Fig. 24 is a perspective diagram showing the top extending cable.

**[0042]** Fig. 25 is a perspective diagram showing the upper retracting cable.

**[0043]** Fig. 26 is a perspective diagram of the leveling system.

**[0044]** Fig. 27 is a schematic diagram of the hydraulic cylinder shown in Figs.  
15 3 and 10 connected to a hydraulic control valve.

**[0045]** Fig. 28 is a side view of the hydraulic cylinder shown in Fig. 27.



**[0046]** Fig. 29 is a schematic diagram showing connections of the control valve to other hydraulic components.

**[0047]** Fig. 30 is a schematic diagram showing the entire hydraulic system of the crane arm shown in Figs. 1-7. Bold lines indicate hydraulic lines. Light lines  
5 indicate electrical lines.

**[0048]** Fig. 31 is a top view of the base section of the hydraulic valve shown in Fig. 27, and further showing connections between ports of the base section and the hydraulic cylinder shown in Figs. 27 and 28.

**[0049]** Fig. 32 is a section view taken along line 32-32 of Fig. 31.

10 **[0050]** Fig. 33 is an enlarged section view of the valve assembly shown in Figs. 27 and 30.

**[0051]** Fig. 34 is a section view taken along line 34-34 of Fig. 33.

**[0052]** Fig. 35 is an enlarged section view of the piston within the hydraulic cylinder shown in Fig. 10.

15 **[0053]** Fig. 36 is a top view of the motor and valve assembly shown in Fig. 30.

**[0054]** Fig. 37 is a front view thereof.

**[0055]** Fig. 38 is a side view thereof.

### DETAILED DESCRIPTION OF THE DRAWINGS

[0056] Turning now in detail to the drawings, as shown in Figs. 1 and 2, a telescoping crane 30 is mounted onto a mobile base 32. The mobile base 32 may be a truck or road vehicle, or a motorized special purpose camera crane base or dolly. Typically, the mobile base 32 will have wheels 34 which drive and steer the mobile base. Four-wheel drive and four-wheel steering may be provided. For smaller scale cranes 30, e.g., up to about 15 feet, the mobile base 32 may be unmotorized, and may be moved or pushed by hand. For larger versions of the telescoping crane 30, or when required due to ground conditions or other use requirements, the mobile base 32 can have electric motors, or internal combustion engines, for driving the wheels 34.

[0057] As shown in Figs. 1 and 2, the crane 30 is mounted on a column 36 on the mobile base 32. The column 36 may be automatically leveled, as described in U.S. Patent No. 4,747,424, incorporated herein by reference, to maintain the crane 36 in a level orientation as the mobile base 32 moves over uneven ground.

[0058] A U-shaped center post 46 is rotatably mounted on the column 36. As shown in Fig. 8, a post 40 on the column 36 extends up through a lower column bearing 42, and upper column bearing 43 secured within a post ring 45 of the center post 46. A cap nut 44 is attached, e.g., threaded, onto the top end of the column post 40, to securely attach the center post 46 onto the column 36 of the mobile base

32, while still allowing the center post 46 of the crane 30 to rotate. As shown in Fig. 5, the centerpost 46 extends up at a rearward angle G, so that the tilt axle 70 is offset behind the pan axis P by a distance DD. This offset, which helps to keep the center of gravity of the arm 35 centered over the pan axis bearings 42 and 43, varies with the arm design, and typically is 1-3 inches. The corresponding angle G is generally 5-15 degrees. An optional potentiometer or angular position sensor 75 has a base attached to the fixed or non-rotating column post 40, and a body linked to and rotatable with the center post 46, to provide an electrical output signal to a controller, such as a control box 275 shown in Fig. 1.

10 **[0059]** Referring back to Figs. 2, and 8, a crane arm 35 is supported on a tilt axle 70 which is pivotably supported on the center post 46. Consequently, the crane arm 35 can rotate about a pan axis P, and can also pivot about a tilt axis T shown in Fig. 8.

**[0060]** Referring to Figs. 1-11, the crane arm 35 includes a first or outer section 52, a second or middle section 54, and a third or inner section 56. As shown in Fig. 8, the first section 52 is supported on the tilt axle 70 via an axle bearing 72. Fixed or non-moving trim weights 48 are placed at the back end of the first section 52. The trim weights 48 may or may not be needed or used, depending on whether non-moving weight from e.g., accessories, is added to the arm in front of the tilt axle.

15

20

**[0061]** A counter weight carrier or tray 50 is movable along the top of the first section 52, from a front or forward position F, when the arm 35 is fully retracted, as shown in Figs. 1, 4, and 5, to a rear or back position R, when the arm 35 is fully extended, as shown in Figs. 2, 6, and 7. Moving or mobile counter weights 58 are

5 attached to the counter weight carrier 50. As shown in Figs. 3, 8, and 9, the counter weight carrier 50 has top rollers or wheels 80 which roll on a roller track 82 attached to the top surface of the first section 52. The counter weight carrier 50 also has side rollers or wheels 84 which roll along the sides of the roller track 82. The top rollers 80 support the weight of the counter weight carrier 50 and moving counter weights  
10 58, and allow the counter weight carrier 50 to roll between the front and rear positions with low force. The side rollers 84 keep the counter weight carrier 50 aligned, side to side, on top of the first section 52, and secure the counter weight carrier vertically against upward movement.

**[0062]** Referring to Figs. 2, 6, 7, 16, 17, 19, and 20, a nose plate 65 is  
15 attached to a nose axle 196 pivotably attached at the front end of the third section 56. A riser or extension 60 can be attached to the nose plate 65 with a mounting bolt 200 and a quick release position pin 202.

**[0063]** In the configuration shown, an extension 60 is used, and a remote camera head 62 is attached at the front end of the extension 60. The camera head  
20 62 is described in U.S. Patent Application Serial No. \_\_\_\_\_, for "Three Axis

Remote Camera Head," filed on February 19, 2004, docket 54767.8065.US00, incorporated herein by reference. Of course, other camera heads may also be used. Alternatively, other camera support plates, risers, drop downs or accessories may be attached directly to the nose plate 65, with no extension 60 and/or camera

5 head 62 being used. In the configuration shown, a camera 64 is attached to a camera platform on the camera head 62. The camera head 62, if used, can provide controlled angular camera movement about pan, tilt, and roll axes, independent of movement of the crane arm 35. Referring to Fig. 19, the nose plate 65 has four or more preferably equally radially spaced apart positioning holes 203. The extension  
10 60 and camera head 62 can be moved from the upright or overslung position, shown in solid lines in the drawings, to an inverted or underslung position, as shown in dotted lines in Fig. 7, or to a 90 degree position, as shown in dotted lines in Fig. 6, by loosening the mounting bolt 200, withdrawing the spring-based position pin 202, then turning the extension 60 to the desired position, releasing the position pin 202,  
15 and retightening the bolt 200. These alternate positions provide added range of camera movement. In addition, the 90 degree positions are useful in balancing the camera head 62.

**[0064]** The crane 30 has a hydraulic system 100 which provides the driving force for extending and retracting the crane arm 35. Referring to Figs. 2, 3, and 27-  
20 30, the hydraulic system 100 includes a hydraulic cylinder 114 attached to the top of the first section 52. A hydraulic cylinder cable 118 extends through the hydraulic

cylinder 114. A first end 120 of the cable 118 extends out through a rear cable seal 136, as shown in Figs. 27 and 35, and extends around a rear hydraulic cylinder cable pulley 126, and is attached to the counter weight carrier 50 via a cable tie, clamp, or turnbuckle 128. Similarly, a second end 122 of the hydraulic cylinder cable 118 extends forward through the hydraulic cylinder 114 from the piston 116, through a front cable seal 136, extends around a front hydraulic cylinder cable pulley 124, and is attached to the counter weight carrier 50, also via a cable tie, clamp, or turnbuckle 128. The cable seals 136 allow the cable 118 to slide through while sealing hydraulic fluid within the cylinder 114.

10 **[0065]** The hydraulic cylinder cable 118 is attached to a piston 116 which is movable back and forth within the hydraulic cylinder 114. As shown in Fig. 35, the piston 116 has front and rear piston crimp extensions 130 which are tightly crimped onto the cable 118. Of course, other attachments, such as screw threads, welding, adhesives, clamping, etc., may equivalently be used. Referring still to Fig. 35, a  
15 piston seal or O-ring 132, backed by plastic or Teflon (Fluorine resins) seal rings 134, provides a sliding seal between the piston 116 and the cylindrical inside walls of the hydraulic cylinder 114. The hydraulic cylinder cable 118 advantageously has internal twisted bundles of high strength filaments, fibers, or wires, surrounded by a plastic or vinyl covering or sheath. The ends of the cylinder 114 are sealed with an  
20 end cap or plug 136. An O-ring 137 in the end cap seals around the smooth covering on the cable, while allowing the cable to slide in and out of the cylinder. As

hydraulic fluid pressure is exerted against either the front or back side of the piston 116, as described below, the piston 116 moves through the hydraulic cylinder 114, correspondingly moving the counter weight carrier 50 in the opposite direction. The hydraulic system 100 also includes other components for driving and controlling the hydraulic cylinder 114. The design and operation of these other hydraulic system components, which are generally located within a hydraulic system enclosure or housing 106 attached to the bottom of the first section 52, is described below. As shown in Fig. 27, the hydraulic cylinder 114, pulleys 124, 126 and cable 118 are provided as assembly 125.

10 [0066] The crane arm 35 also includes a drive system 102, which extends and retracts the second section 54 and the third section 56, upon actuation of the hydraulic cylinder 114. Referring to Figs. 3 and 23, a second section rear drive cable 140 (or pair of side-by-side cables) is attached to the top surface of the second section 54, via a cable tie, clamp or turnbuckle 146, adjacent to the back  
15 end of the second section 54, extends around a rear pulley 144 attached to the back end of the first section 52 and is attached near the back end of the second section 54. A second section forward drive cable 147 is attached to the counter weight carrier 50, extends forward around a front pulley 142, supported near the front end of the top surface of the first section 52, and is attached to the top surface of the  
20 second section 54, near the back end of the second section 54. Consequently, as

the counter weight carrier 50 moves along the top of the first section 52, the second section 54 is moved by an equal amount, in an opposite direction.

[0067] The drive system 102, as shown in Figs. 3 and 24, also includes a top extending cable 152, and a symmetrical or mirror image or bottom extending cable

5 153, shown in profile in Fig. 8. As shown in Fig. 24, the back end of the top extending cable 152 is attached to a back wall of the first section 52 at a cable anchor or tie point 156. The top extending cable 152 extends forward, between the second section 54 and the third section 56, runs around a top drive pulley 150, secured to the inside top surface of the second section 54 and is attached at the  
10 rear top surface of the third section 56, via a cable anchor or turnbuckle 154. The top drive pulley 150 is mounted on the top inside surface of the second section 54, near the front end of the second section 54. The bottom extending cable 153 has the same design. As the second section 54 is extended out of the first section 52, via movement of the counter weight carrier 50 driven by the hydraulic cylinder 114,  
15 the drive pulleys 150 (one each on the top and bottom of the second section 54) pull the third section 56 out of the second section 54. Accordingly, when the hydraulic cylinder 114 is actuated to extend the crane arm 35, the third section 56 extends out of the second section 54 by the same amount ( and in the same direction) as the second section 54 extends out of the first section 52. This rearward movement of  
20 the counter weight carrier 50, forces the forward movement of the third section 56 at double the (rearward) movement of the counter weight carrier.



**[0068]** The drive system 102 also includes a top retraction or pull back cable 158, and a bottom retraction or pull back cable 159, as shown in Figs. 8 and 25.

Referring to Fig. 25, the first or front end of the top pull back cable 158 is attached to the top inside surface of the first section 52, with a cable anchor or turnbuckle 162.

5 The top pull back cable 158 then extends rearwardly, between the first section 52 and the second section 54, to a retraction pulley mounted on the top back end of the second section 54. For purposes of illustration, the bottom extension and retraction cables and pulleys are not shown in Figs. 24 and 25. However, they are duplicates of the top cable and pulley designs shown in Figs. 24 and 25. Top and bottom  
10 cables and pulleys are used to provide precise, smooth and more evenly balanced telescoping movement of the sections. However, single cable designs may also be used. Claims and sprockets may also be used in place of cables and pulleys.

**[0069]** The top retraction or pull back cable 158 extends around the top retraction pulley 160, passes through the slot or opening in the second section, and  
15 is attached to the top back end of the third section 56 with a cable anchor or tie 156. The bottom pull back cable 159 has the same design. Both retraction or pull back pulleys 160 and 161 are oriented in a plane P at an angle of 20-45 and preferably 30 degrees, to allow the pulleys to fit within a compact space between the second and third sections, as shown in Fig. 8.

[0070] Referring momentarily to Fig. 25, as the second section 54 is retracted or pulled back into the first section 52, via the hydraulic cylinder 114 moving the counter weight carrier 50, the top and bottom retraction pulleys 160 and 161 on the second section 54, move rearwardly with the second section 54, pulling the third  
5 section 56 back into the second section 54.

[0071] Turning momentarily to Fig. 7, with smaller versions of the crane arm 35 (e.g., having an extended length of about 15 feet, as measured from the tilt axle 70 to the nose axle 196, the moving sections 54 and 56 may be straight. For longer versions of the crane arm 35, the second and third sections 54 and 56 are  
10 advantageously formed with a slight upward radius of curvature R. The radius R will vary, depending on bending and deflection characteristics of the sections. Stiffer sections (i.e., having a shorter length, thicker walls, or greater moment of inertia) will have less curvature, i.e. R will be greater. As one example, where the second and third sections are an 8 inch and a 6 inch square aluminum tube, each about 170  
15 inches long (i.e., for a crane arm having an extended length of about 31.5 feet), R is preferably 8,000-20,000, 10,000-18,000, or 13,000-15,000 inches. This upward curvature helps to compensate for sagging of the arm 35 when loaded. With an average payload of about 150lbs (including the camera 64, camera head or frame 62 and extension 60), and with arm at a 30° elevation angle, the upward curvature  
20 R offsets the bending deflection, and the arm 35 is straight. With different payloads and elevation angles, the arm 35 will curve slightly up or down, but it will always be

straighter than an arm without any fault in upward compensating curvature R.

Having the arm 35 remain straighter improves performance because it helps to keep the center of gravity of the payload centered on the central axis of the arm 35.

Consequently, the arm 35 is less subject to eccentric loads or torsional loading,

5 resulting in a more stable camera platform. In addition, the straighter arm 35 is more easily kept in balance.

[0072] Referring to Figs. 12, 13, 21, and 22, the third section 56 is supported within the second section 54 by rollers 112 mounted on roller mounting plates or brackets 110. The roller brackets 110 are attached to the inside surface of the front  
10 end of the second section 52. Specifically, two roller brackets 110 are attached to the inside top, bottom, left, and right interior sides of the front end of the second section 52, for a total of 8 roller brackets. As shown in Figs. 12 and 21, the roller spread or footprint, i.e., the distance S between the front and rear rollers is minimized. This reduces the overlap between the second section 54 and the third  
15 section 56 when the crane arm 35 is fully extended. Consequently, the crane arm 35, while typically having only 2 moving sections, has an increased reach, while also remaining relatively compact when retracted. The rollers 112 are preferably made of a relatively soft plastic or non-metal, preferably having a Shore hardness of 70-90. This provides for smooth and quiet rolling between the sections. In addition, the  
20 rollers 112 help to absorb and reduce transmission of vibration between the sections. The rollers 112 and brackets 110 are similarly used to telescopically

support the second section 54 within the first section 52. For larger versions of the crane arm 35, the dimension S is increased, to better carry larger loads. As

examples, for a crane arm 35 with about a 15 foot length (measured from the tilt axle to the nose axle) the dimension S is about 11 or 12 inches. With a crane arm

5 having a length of about 30 or 31 feet, the dimension S is about 23 or 24 inches.

The brackets 110 are advantageously bolted into position and fit tightly around the section they support. As shown in Figs. 12 and 13, cutouts, grooves, or recesses 113 may be made in the sections, to provide clearance for the rollers 112. For clarity of illustration, only one of the brackets 110, and only some of the rollers 112, are

10 shown in Fig. 12, and they are omitted entirely from Fig. 13. The arm sections 52, 54, and 56 are preferably hard anodized, to provide a hard surface which the rollers 112 roll on. Felt, or non-absorbing nitrile, rubber or plastic strips or wipers attached around the openings of the first section 52 and the second section 54 can be provided to wipe the second section 54 and the third section 56, as the crane arm  
15 35 extends and retracts.

**[0073]** A mechanical stop 108 at the back end of the third section 56 contacts a bracket 109 on the second section 54 to provide a hard mechanical stop and to limit the extension of the third section 56 out of the second section 54. The extension of the third section 56 out of the second section 54 is also limited by the  
20 length of the extension cables 152 and 153.

**[0074]** Referring to Fig. 8, the first section 52, second section 54, and third section 56 are preferably square or nearly square aluminum tubes. In the design shown in the drawings, which provides an extension of travel length of approximately 112 inches, the first section is a 10 x 10 3/4 inch square tube, the second section is an approximately 8 inch square tube, and the third section is an approximately 6 inch (outside dimensions) square tube. Larger and smaller versions can of course also be made. The sections may be formed as extrusions, weldments, bolted plates, or in similar ways. Drain holes may be provided in the sections 52 and 54, to reduce buoyancy forces when they are submerged. As shown in dotted lines in Fig. 25, a fourth section 57 may also be used, as a third moving section, to further increase the reach of the arm. The size, shape and number of telescoping sections, material selections, actuator (e.g., hydraulic, electric, etc.) type, attachment techniques and accessories, are not essential to the invention and can be changed.

**[0075]** The crane arm 35 includes a leveling system 104 to maintain the nose plate 65, and any accessory attached to it, such as the extension or riser 60 and the camera head 62, in a horizontal or level orientation, regardless of the elevation angle AA (shown in Fig. 2) of the crane arm 35. The leveling system 104 consequently maintains the camera 64 supported directly or indirectly by the nose plate 65, in a horizontal position.

[0076] Referring now to Figs. 3, 14, 15, 19, 20, and 35, the leveling system 104, on the right side of the crane arm 35, includes a cable pulley 182 rigidly attached to the center post 46. The back end of a spring cable 184, which includes a spring 186, is attached to the cable plate 182. The front end of the spring cable 184 is attached to a rear leveling axle assembly 188. The rear leveling axle assembly 188 is pivotably supported on front end frame 180 attached to the front end of the first section 52. A first end 189 of a leveling cable 190 is attached to an inside pulley on the rear leveling axle assembly 188. The leveling cable 190 extends rearwardly from the axle assembly 188, over an idler 194, around a rear leveling cable pulley 192 rotatably attached to the rear right side of the second section 54, and then extends forward under a second idler 194 and is attached to a nose pulley 198 joined to the nose axle 196. The same components are symmetrically provided on the left side of the crane arm 35.

[0077] Referring to Figs. 19 and 20, the leveling cable 190 wraps around the nose pulley 198, and is attached to e.g. clamped within the nose pulley 198.

Referring to Figs. 2 and 3, the weight of the payload, e.g., the camera 64, as well as any camera head 62 or extension 60, if used, exerts a downward or clockwise (in Figs. 2 and 3) torque acting on the nose axle 196. Consequently, the leveling cable 190 and spring cable 184 are typically maintained under constant tension. The spring 186 is selected with a spring constant to provide a level of flexibility in the leveling system 104. In the event that the nose plate 65, extension 60, or camera

head 62 is moved forcefully into an overhanging surface or ceiling, the spring 186 extends, allowing the nose plate 65 to move downwardly (clockwise in Fig. 3) to reduce or avoid damage to the crane arm 35, extension 60, or camera head 62.

The spring 186 may be omitted, or it can be locked out by a rigid cable link 185, or

5 dampened with a shock absorber 187, shown in dotted lines in Fig. 14. During extension of the crane arm 35, the rear leveling cable pulley 192, which is attached to the second section 54, moves forward at one-half the rate of the nose pulley 198 supported on the third section 56. Accordingly, tension in the leveling cable 190 is not affected by extending or retracting the crane arm 35. A clutch 195 may also be  
10 provided between the nose axle 196 and the nose pulleys 198, to allow the nose plate 65 to pivot downwardly under excessive momentary loading.

**[0078]** The hydraulic system 100 is shown in detail in Figs. 3, 11, and 27-34.

The hydraulic system 100 provides the motive force for moving the counter weight carrier 50 and simultaneously extending or retracting the crane arm 35. In normal  
15 and preferred operation, the crane arm 35 is balanced. Forward, or upward movement of the payload is compensated by rearward or downward movement of the counter weight carrier 50 and the mobile counter weights 58. Accordingly, the hydraulic system 100 generally need only overcome forces of friction and inertia, to extend or retract the crane arm 35. As a result, the hydraulic system 100 is compact  
20 and energy efficient. The components making up the hydraulic system 100, which are shown in Fig. 30, are preferably contained within the hydraulic system housing

106, except for the hydraulic cylinder 114 which extends along the top surface of the first section 52.

**[0079]** As shown in Fig. 30, a pump 224 driven by an electric motor 220 charges or pressurizes an accumulator 228. Instead of the motor 220, a hand pump 233 may be used. The battery 222 can be charged by an external AC plug-in connection 237.

**[0080]** The accumulator 228 is connected via fluid lines to a valve assembly 230, and also to a pressure switch 227, which automatically switches off the motor 220 when a pressure limit is reached within the accumulator 228. A pressure gauge 229 linked to the accumulator 228 is visible through a window or opening in the enclosure 106. A battery 222 connects to the motor 220 through a on/off switch 236 and the pressure switch 227. An on/off indicator 235 is viewable through a window or opening in the enclosure 106. A relief valve 240 joins into a T-fitting in the line linking the accumulator 228 and the valve assembly 230, to relieve excess pressure in the accumulator 228, and return hydraulic fluid to a reservoir or tank 226. The reservoir 226 provides unpressurized hydraulic fluid, through a filter 225 and a check valve 231 to the inlet of the pump 224.

**[0081]** A valve shaft 232 extends through the valve assembly 230. Control knobs 234 are provided at each end of the valve shaft 232, so that the valve assembly 230 can be controlled from either side of the crane arm 35. Referring to



Figs. 36-38, a chain or belt 290 connects a shaft sprocket 296 on the valve shaft 232 with a motor sprocket 294 on a valve control motor 242. An adjustment and potentiometer idler sprocket 298 is also engaged with the chain 290, and is linked to a potentiometer 244. The potentiometer 244 and the valve control motor 242 are both connected to an electronic controller 248. The potentiometer 244 has a small cable transducer attached to the counter weight carrier and provides electrical signals to the controller 248 based on position, and speed and direction of movement of the counterweight carrier, which is proportional to the extension position of the arm 35. Stops limit rotation of the valve 230.

10 **[0082]** Referring to Figs. 27, and 31-34, the valve assembly 230 includes a valve block 250 attached to a base 252. First, second, third, and fourth valve pins 259, 261, 263, and 265 are positioned within first, second, third, and fourth bores 258, 260, 262, and 264 in the valve block 250 and base 252, forming four valves. The first bore 258 connects with the third bore 262 via a first or rear drive port 254, as shown in dotted lines in Fig. 31. Similarly, the second valve bore 260 connects with the fourth valve bore 264 via a second or front drive port 256, also shown in dotted lines in Fig. 31. Plugs 261 seal drill openings made during manufacture, to provide right angle bends in the internal ports. The first or rear drive port 254 of the valve assembly 230 is connected to a rear port 216 of the hydraulic cylinder 114. 15 The second or front drive port 256 of the valve assembly 230 is connected via a hydraulic line to a front port 218 of the hydraulic cylinder 114, as shown in Figs. 27 20

and 31. A high pressure inlet port 266 is connected via a hydraulic line to the accumulator 228. A low pressure inlet port 268 in the valve block 250 is connected via a return hydraulic line to the reservoir 226. Each of the valve pins 259, 261, 263, and 265 is biased upwardly or into a closed position via a spring 270. In the up or closed position, a head on the hardened valve pin seals against a hardened valve seat 274 pressed and/or swaged into the valve body at the lower end of each bore. A valve piston 276 is centered on a shoulder and threaded onto each of the valve pins. This design provides a highly reliable and durable seal of each bore which is very resistant to leaking, even at high pressures. The springs 270 bias the valve pistons 276 against cam lobes 272 on the valve shaft 232. Small clearances assure seating of the valve pins in the valve seat, and provide a detent. The cam lobes are preferably 90 degree offset circles, to provide smooth (sinusoidal) movement of the valve pins. As shown in Fig. 33, O-rings 278 and 280 seal the pin bores.

**[0083]** The valve shaft 232 is set up with stops that limit rotation to about +/-

85 degrees. This allows for complete valve control, without the need to remove and reposition the users hand on the control knob 234. Ergonomics are improved. Using a potentiometer 244 having a 170 degree range of movement in one direction, plus 170 degrees in the other direction, and 2:1 tooth ratio between the shaft sprocket 296 and the idler 298, allows for use of the potentiometer over its entire range, for greater control sensitivity. As the valve shaft 232 is turned, either manually by gripping and turning the control knob 234, or automatically via the valve control

motor 242 and electronic controller 248, the ports in the valve assembly 230 are opened and closed, to control movement of the piston 116 within the hydraulic cylinder 114. For example, with the valve shaft 232 at a zero degree position, all ports are closed and no movement of the crane arm occurs. To begin to extend the

5 crane arm 35, the valve shaft 232 is turned (clockwise in Fig. 30). This opens first and fourth valves, connecting the rear port 216 to the accumulator and simultaneously connects the front port 218 to the reservoir, through the valve assembly 230. Hydraulic fluid pressure on the back of the piston 116 exceeds the fluid pressure on the front surface of the piston, causing the piston 116 to move

10 forwardly (to the right in Figs. 3, 27, and 30). The hydraulic cylinder cable 118 is driven counter-clockwise (in Fig. 30). The counter weight carrier 50, which is attached to the hydraulic cylinder cable 118 moves rearwardly upon the top surface of the first section 52. Referring momentarily to Fig. 23, as the counter weight carrier 50 is driven rearwardly, the second section drive cable (or pair of cables) 140

15 drives the second section 54 forwardly. Referring momentarily to Fig. 24, this forward movement by the second section 54 simultaneously drives the third section 56 forwardly, via the forward movement of the third section drive pulley 150 and 151 (both attached to the second section 54) acting on the top and bottom extending cables 152 and 153. As a result, the third section 56, moves outwardly to the

20 desired camera position. To reverse direction and retract the crane arm 35, the valve shaft is turned back (counter clockwise in Fig. 30) through the stop or closed

position. This closes the first and fourth valves and then opens the second and third valves. Now, the hydraulic connections to the hydraulic cylinder are reversed, driving the piston in the hydraulic cylinder in the reverse direction and retracting the arm. The speed of extension and retraction will increase with increasing movement of the valve shaft away from the zero or closed position, due to the shape of the cams. Since the valve assembly to 30 is pressure compensated, only small amounts of force are required to turn the valve shaft 232 and open and close the valves.

**[0084]** In use, the crane 30 is shipped to the filming location in the retracted position. The trim weights 48, and the mobile counter weights 58, and any riser or extension 60 and camera head 62 are preferably separated from the camera crane 30 and transported individually to make transportation easier. At the filming location, the crane 30 is attached to a mobile base 32. The riser or extension 60 and the camera head 62 (if used) are attached to the nose plate 65. The camera and any accessories are attached to the camera platform. Mobile weights 58 are added to the weight carrier until the arm is balanced. The center of gravity CG of all of the moving elements is therefore then fixed, and remains on the pan axis P shown in Fig. 15, whether the arm is extended or retracted or in between.

Correspondingly, the center of gravity CG of the arm 35 also remains centered over the pan bearings 42 and 43. As a result, during panning movement, the weight load of the arm remains centered on the bearing. Deflection during panning of the center

post 46, or of the frame or tires of the mobile support, is reduced or avoided entirely.

This provides a more stable support for the camera. If needed, trim weights are added to precisely balance the crane arm 35. While the trim weights will typically be added at the back end of the arm, for some uses, they may also be attached near  
5 the front end of the arm.

**[0085]** The camera head 62, if used, is balanced using known techniques, conveniently by moving the camera head 64 into a 90 degree position, as shown in Fig. 6. The hydraulic system 100 is charged, preferably by plugging wall current into the connector or plug 237 within the electrical system of the hydraulic system 100.

10 Alternatively, power from the battery 222, controlled by the switch 235 is used to power the motor 220 driving the pump 224. As the hydraulic system 100 operates with only small volumes of hydraulic fluid, the accumulator 228 can be quickly charged. The crane 30 is then ready for use in filming.

**[0086]** The camera 64 is brought to the desired position by pivoting the crane  
15 arm 35 about the pan axis P shown in Fig. 8, and by pivoting the crane arm 35 about the tilt axis T. These pivoting movements are typically performed manually. As the arm 35 is balanced, little or no lifting force is required, and manual or hand force is required only to overcome friction and inertia. Alternatively as shown in Fig. 1, crane arm pan and/or tilt axis motors or actuators 74 and 76 can be provided on  
20 the mobile base or crane arm to perform these operations. The actuators 74 and

76, as well as the hydraulic control valve assembly 230, may optionally be remotely controlled, via a control box 275 connected to each of them via a wired or wireless connection. This allows the entire crane 30 to be remotely controlled. Pan and tilt sensors 75 and 77 (shown in Figs. 8 and 2) provide rate, direction, and/or position  
5 information to the control box 275.

**[0087]** The telescoping movement of the crane arm 35 is initiated by turning the control knob 234. This actuates the valve assembly 230, supplying hydraulic fluid to the hydraulic cylinder 114 to drive the piston 116, counter weight carrier 50, and in turn the second and third sections 54 and 56, as described above. The  
10 controller 248 can be set up or programmed to actuate the valve control motor to operate the valve assembly. This allows the crane arm 35 to automatically move to pre-selected positions, or to perform pre-programmed movements. (The remote control box 275 may be similarly programmed, with positions or movements (pan, tilt, telescope extend/retract) for the entire crane 30, and/or the camera head 62.)

15 **[0088]** As shown in Fig. 1, using the camera head 62 allows the center of gravity CGP of the payload (typically the camera 64 and head 62) to be positioned on a horizontal central axis CC (shown in Figs. 3-5) of the crane arm 35, as the sections or segments of the camera head 62 are adjustable. Positioning the center of gravity CGP of the payload on the crane arm center line CC reduces or eliminates  
20 twisting or torsion of the crane arm 35 during rapid arm movements. Accordingly,

the camera can be quickly moved from one position to another, without excessive generation of vibration or resonance in the arm 35. This provides a more stable camera support.

**[0089]** Referring to Figures 1 and 2 the counter weight carrier is movable

5 along substantially the entire length of the first section 52. With the crane arm 35 in the retracted position, the counter weight carrier 50 is in front of the center post 36.

As the range of movement of the counter weight carrier 50 is increased, in contrast to prior designs, fewer mobile counter weights 58 are needed for balancing.

Accordingly, the weight of the entire crane 30 is reduced. This allows for easier  
10 transportation and setup. In addition, less force is needed to move the mobile counter weights, reducing the size and weight of the hydraulic system. The crane arm 35 is always maintained in balance, as the center of gravity CG of the arm is fixed. Even when the counter weight carrier 50 moves forward of the center post 46, the crane arm 35 remains balanced, with the CG forward of the tilt axle.

15 **[0090]** The hydraulic system 100, including the hydraulic cylinder 114, and the valve assembly 230 also form a separate inventive subsystem having other uses. This subsystem may be used in other equipment where an actuator applies force over a relatively long distance. In a basic form, the hydraulic system includes a piston slidable within a hydraulic cylinder. A first cable is attached to a first end of  
20 the piston and a second cable is attached to a second or opposite end of the piston.

The cables extend through the hydraulic cylinder and pass out of the hydraulic cylinder through cable seals. The cable seals allow the cables to slide into and out of the cylinder, while maintaining pressurized hydraulic fluid within the cylinder. The cable seals optionally may also provide a wiping action on the cables, so that the cable sections outside of the cylinder are substantially dry and free of hydraulic oil (even though the sections of the cables within the cylinder are immersed in or surrounded by hydraulic oil). However, the wiping action is not essential. Since the piston can move through substantially the entire length of the cylinder (while pulling the first or second cable with it), a very long actuation length or stroke is provided, in a lightweight and compact design. The first and second cables can optionally be formed as single cable loop. To better provide a seal against the cables sliding through the cable seals 136, the cables 120, 122 may be formed with a smooth outer coating, sheath or jacket (of e.g., plastic) surrounding a core of high strength fibers (of e.g., steel, Nylon, etc.)

**[0091]** The valve assembly 230 also forms a separate inventive subsystem usable as well in other types of equipment and machinery, where precise hydraulic movements are used and with no leakage, even at high pressures.

**[0092]** The crane arm 35 can be more safely used in wet areas and environments, because it can operate entirely on low voltage battery power, or can operate without any electrical power at all. While the hydraulic system



advantageously includes a battery and motor, these are low voltage components (typically 12, 24 or 36 VDC). The hydraulic system can also be operated using the hand pump. The accumulator, once charged with hydraulic pressure, can also drive the crane arm 35 through several extension/retraction cycles, without any pumping or external power. The low voltage battery can be periodically recharged when the crane arm 35 is not in use. Alternatively, it can be quickly replaced with a fresh battery, while the crane arm is in use. This avoids the need for connecting 110VAC or 220VAC line current electrical cables to the crane arm (as is often required with existing crane arms). As a result, safety relating to proper equipment grounding or shock hazards are reduced, since the crane arm 35 does not require line current or external grounding. Thus, in wet environments, the ability to operate only on battery power, or hand pump power, is a significant improvement. The need for inverters and transformers associated with use of 110 or 220VAC power, is also avoided. In addition, since external electrical power is not needed, the entire crane and mobile base can operate more freely, as the drag and wheel obstacles created by external electrical cables is avoided. Moreover, the 12, 24 or 36VDC electrical system of the crane 35, if used, is compatible with the electrical power systems of most cameras and remote camera heads.

**[0093]** Thus, a novel camera crane, hydraulic system, actuator and valve

have been shown and described. Changes and substitution may of course be made

without departure from the spirit and scope of the invention. The invention, therefore, should not be limited, except to the following claims and their equivalents.